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Abstract

A tallgrass prairie located in northeastern Illinois was revisited to update relationships in a 2002 study between the presence of mounds of *Lasius claviger* (Formicidae) and characteristics of the soil and prairie flora. Reconstruction of the 7.1 ha site began 26 years ago. As in 2002, mounds of *L. claviger* did not appear to be affecting soil temperature, but were associated with higher floral richness and differences in soil moisture at 10 cm depth as compared to control sites having the same major grass type. In addition, soil organic content and above-ground plant biomass were significantly higher where mounds were present. Findings indicate a continued effect of the ant on soil and flora in the reconstructed prairie.

Soil dwelling ants (Formicidae) have important ecological roles in material transport, altering soil texture, nutrient enriching the soil, and tunneling which can aerate and affect water infiltration (Jurgensen et al. 2008, Lobry de Bruyn 1999, Wagner et al. 2004). They can promote the growth of microflora (Dauber et al. 2001), disperse seeds (Handel et al. 1981, Rissing 1986, Schütz et al. 2008), and serve as major consumers of plant and animal tissues, directly or indirectly by tending herbivorous homopterans (Soulé and Knapp 1996, Stiles and Jones 2001, Wilson 1971). Through multiple ways, soil ants regulate community productivity and structure (Beattie and Culver 1977, Lesica and Kannowski 1998, Rissing 1986, Schütz et al. 2008, Soulé and Knapp 1996). For these reasons, ants cannot be overlooked in ecological restoration and have been used as indicator species to restoration success (Andersen and Sparling 1997, Boris et al. 2009, Fagan et al. 2010, Lobry de Bruyn 1999).

Ants have significant effects in restoration of tallgrass prairie, particularly during early stages of restoration where they can create spatial heterogeneity in soil and vegetation (Lane and BassiriRad 2005). The tallgrass prairie largely has been eliminated in the Midwest. Efforts to reverse losses and preserve remaining tallgrass biodiversity have included ecological restoration and reconstruction of the system. In Illinois, examples of these efforts include the 7600 ha Midewin Prairie, the 400 ha Fermilab tallgrass prairie, and many smaller sites to include the 7.1 ha Russell R. Kirt Tallgrass Prairie, the location of this study. This last site, typical of other reconstructed plots in the Chicago metropolitan area, is space limited, isolated in a suburban sea, and was begun on land that had little resemblance to the original prairie. The Russell R. Kirt plot was reconstructed beginning in 1984 on substrate evacuated during construction of the campus of College of DuPage (Kirt 1996). Reconstruction was only concerned with restoring prairie flora to the area. Consumers, to include ants, have been left to colonize from the surrounding environment.

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This paper examines changes to soil and the flora associated with *Lasius claviger* (Roger) (= *Acanthomyops claviger*), the major mound-building ant in the Russell R. Kirt prairie. The study, conducted during the summer of 2010, revisits the ant population in the plot 8 years after the completion of an earlier study (Petersen et al. 2004). *L. claviger* is a subterranean ant that tends soil homopterans (Burrill and Smith 1919, Stuart and Polavarapu 2002). Its mounds may exceed 40 cm in diameter. In the current study site, the ant forms mounds at the bases of tall grass, including big bluestem (*Andropogon gerardii* Vitman) and prairie dropseed (*Sporobolus heterolepsis* Gray). In a 2002 study, floral richness was higher; soil organic content and temperature were unchanged; and soil moisture was lower during much of the growing season where mounds of *L. claviger* were located (Petersen et al. 2004). Lane and BassiriRad (2005) observed diminishing effects of ant mounds on soil moisture, N content, and C content over 26 years in the much larger reconstructed tallgrass prairie located at Fermi National Accelerator Laboratory, 12 km from our plot. They attributed the loss in heterogeneity to increased plant establishment through time as influenced by ant presence. Hence, we were interested seeing how these trends in soil and plant heterogeneity persisted in our 26 year- old plot.

Methods

Reconstruction of the Russell R. Kirt Tallgrass Prairie began in 1984. Dominant grasses of the Russell R. Kirt Tallgrass Prairie include big bluestem (*Andropogon gerardii* Vitman) and prairie dropseed (*Sporobolus heterolepis* Gray). Flora include over 100 species, largely forbs. The prairie was burned annually until 2006 when selective burning was begun to create the landscape variability which can be critical to the persistence of some species (Fuhlendoft and Engle 2001). The southern portion of the prairie, where 9 mounds of *L. claviger* in this study were located, was burned during March, 2010. The northern portion, which contained the remaining 16 mounds of *L. claviger* under study, had not been burned for 3 years. All mounds were either associated with big bluestem or prairie dropseed.

Measurements of soil moisture, soil temperature, fraction organic content, flora richness, and above-ground plant biomass were taken from mounds, and control sites lacking mounds. Within 1 to 3 m of each *L. claviger* mound, a control was located that was comprised of the same major grass type of the mound, but otherwise randomly selected. Samplings of soil moisture and temperature at 10 cm depth were taken using an Aquaterr Temp-200 meter (Aquaterr Instruments, Costa Mesa, CA) beginning late April and proceeding at 2 week intervals through September. Preliminary core analysis of mounds yielded ants at this depth. Measurements of some mounds were skipped when previous heavy rains prevented access to their location. All measurements for a particular sampling period were taken between 1 pm and 3 pm on the same day. Fraction organic content was determined by taking soil cores at 10 cm depth from each site during July, oven-drying the soil to a constant weight at 60°C, and then burning the soil at 600°C for 6 hours in a muffle furnace. Soil cores from mounds were examined for homopterans prior to drying and burning to test the possibility of tending by *L. claviger*. Floral richness was recorded during July by counting the number of plant species found within a 1-m radius of the center of a mound or control site. Above-ground plant biomass was measured by harvesting all material above 5-cm height during late September when the vegetation had senesced, and then oven-drying samples to a constant weight at 60°C.

Data analysis- Statistica (StatSoft 2001) was used in all statistical procedures.

Repeated-measures analysis of variance (ANOVA) was used to analyze soil moisture and soil temperature data to determine if statistically significant differences exist between *L. claviger* mounds and control sites. Arcsine √ transformation was used to normalize data distribution and of moisture content or $\log_{10}$ temperature (°C) was treated as the dependent variable per ANOVA. Sample period provided the within-subject measure, while mound presence, grass type based on mound appearance, and burning interval (1 or 3) provided between-group factors. Paired Student t-tests were used to examine differences based on presence of *L. claviger* nests in arcsine √ transformation of fraction organic content, square-root transformation of floral richness, and log10 transformation of plant biomass.

Results

Since the 2002 study, mounds in the Russell R. Kirt Prairie have been the subject of ongoing observation. At least 10 mounds have endured over the 2002-2010 time frame. The effects of mound presence and sample period on soil moisture were significant (Table 1). Mean fraction soil moisture was lower in ant mounds than control sites (Fig. 1). Grass type and burning interval did not appear to have significant effects on soil moisture. Mound presence, grass type, or burning interval did not appear to effect soil temperature (Table 2). Soil organic content, floral richness, and above-ground plant biomass were significantly higher where mounds of *L. claviger* were present (Table 3). While *L. claviger* workers were common within soil samples, no homopterans were found. Sampling of *L. claviger* mounds not included in our study only yielded one root aphid.

Table 1. Repeated-measures ANOVA on arcsine √ (fraction soil moisture) at 10 cm depth where *Lasius claviger* mound presence, grass type, and time interval of plot burning (within 1 year or 3) are between-group factors and sample period, the within-subject effect.

Effects	**df**	***F***	***P***
Between subjects			
Mound presence	1	28.58	<0.001
Grass type	1	0.35	0.558
Last burn	1	1.40	0.249
Mound presence × Grass type	1	<0.01	0.982
Mound presence × Last burn	1	0.40	0.533
Grass type × Last burn	1	2.95	0.100
Mound presence × Grass type × Last burn	1	<0.01	0.961
Error	22		
Within subjects			
Sample period	11	20.57	0
Sample period × Mound presence	11	1.71	0.071
Sample period × Grass type	11	0.86	0.581
Sample period × Last burn	11	6.41	0
Sample period × Mound presence × Grass type	11	1.05	0.405
Sample period × Mound presence × Last burn	11	1.16	0.315
Sample period × Grass type × Last burn	11	1.23	0.265
Sample period × Mound presence × Grass type × Last burn	11	0.55	0.868
Error	242		

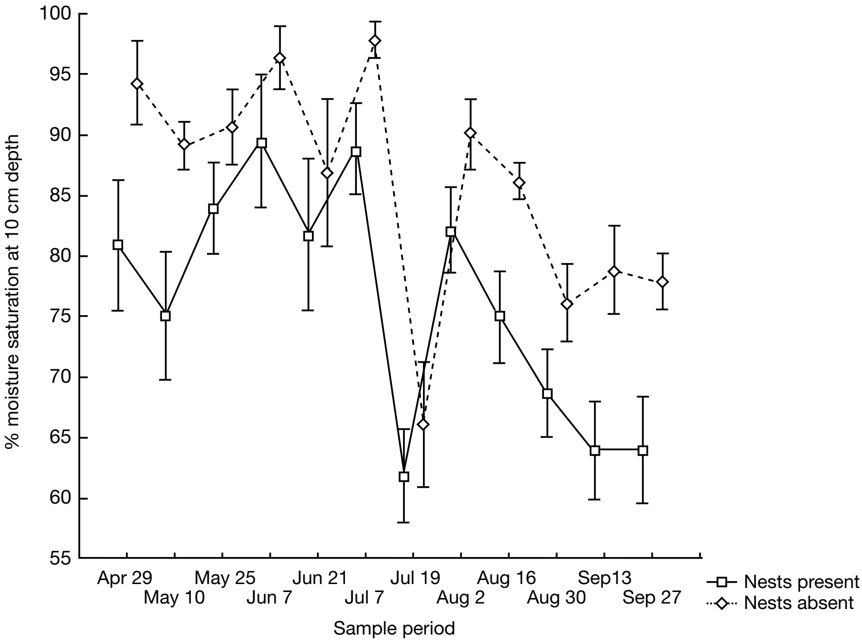

Figure 1. Percent soil moisture (sample ± 95% confidence interval) according to the presence of *Lasius claviger* mounds in grass clumps. Data have not been transformed.

Table 2. Repeated-measures ANOVA on log10 (soil temperature) at 10 cm depth where *Lasius claviger* mound presence, grass type, and time interval of burning (within 1 year or 3 years) are between-group factors and sample period, the within-subject effect.

Effects	**df**	***F***	***P***
Between subjects			
Mound presence	1	0.45	0.510
Grass type	1	0.45	0.511
Last burn	1	0.71	0.409
Mound presence × Grass type	1	0.14	0.707
Mound presence × Last burn	1	0.40	0.535
Grass type × Last burn	1	0.13	0.725
Mound presence × Grass type × Last burn	1	0.11	0.740
Error	22		
Within subjects			
Sample period	11	48.29	0
Sample period × Mound presence	11	0.23	0.996
Sample period × Grass type	11	0.35	0.973
Sample period × Last burn	11	2.13	0.019
Sample period × Mound presence × Grass type	11	0.19	0.998
Sample period × Mound presence × Last burn	11	0.21	0.997
Sample period × Grass type × Last burn	11	0.51	0.895
Sample period × Mound presence × Grass type × Last burn	11	0.21	0.997
Error	242		

Table 3. Summary (mean ± standard error) of soil organic fraction, floral richness, and above-ground plant biomass according to *Lasius claviger* mound presence. Results of t-tests between mound and control sites are provided. Organic soil fraction was arcsine $\sqrt{x_i}$ transformed, floral richness was $\sqrt{x_i}$ transformed, and plant biomass was log10 (x_i) transformed in t-testing. All n = 25.

	Mounds of *Lasius claviger* present	**Control sites with mounds absent**	***t***	***P***
Soil organic fraction	0.14 ± 0.03	0.08 ± 0.01	2.285	0.031
Floral richness	6.64 ± 0.29	5.72 ± 0.31	2.548	0.018
Above-ground plant biomass (g)	90.67 ± 17.26	65.37 ± 12.25	3.319	0.003

Discussion

In keeping with the 2002 study, soil moisture and flora richness continued to be significantly different based on the presence of *L. claviger* mounds (Petersen et al. 2004). In addition, soil organic content and above-ground plant biomass were higher. Elevated organic content in mounds of *L. claviger* can be explained by the influx of materials, microbial colonization, accumulation of ant waste, and greater plant growth in and around mounds. Higher soil organic levels may not have been evident 18-years after initial restoration due to slow rates of accumulation associated with the establishment of our restored plot. Nutrient enrichment associated with higher organic content is commonly observed in ant mounds (Jurgensen et al. 2008, Wagner et al. 2004) and can explain greater plant growth. We question the importance of exudates from soil homopterans to the diet of *L. claviger*. The absence of homopterans in soil cores may reflect a limitation of this sampling method. However, a dietary study of *L. flavus* which also was assumed to tend soil homopterans, indicated more of a predatory diet (O'Grady et al. 2010). Such a possibility also should be investigated with *L. claviger* as inputs from predation may also explain the higher organic content of soil from mounds. Soil modification created by mounds may facilitate plant colonization and growth. An increase in these plant parameters would not be expected if homopteran infestation was prevalent.

Soil moisture, as in 2002, was found to vary significantly based on the presence of *L. claviger* mounds. Tunneling by ants is known to affect the porosity of soil (Lobery de Bruyn 1999), promoting water drainage and explaining the tendency for soil moisture levels to be lower in mounds and perhaps favoring higher flora richness and above- ground biomass. Elevated mounds also should encourage run-off and less water capture. Bucy and Breed (2006) found that vegetation clearing by harvester ants functions to expose soil to more solar radiation, increasing surface temperatures. Our findings of greater above-ground plant growth on mounds do not support grazing or temperature differentiation. However, shading can explain the lack of temperature differences between mound and control sites in our study versus Bucy's and Breed's (2006). The absence of an effect of burning interval based on mound presence may reflect the insensitivity *L. claviger* has to fire as seen among ants in fire-disturbed landscapes (Parr and Andersen 2008).

Our ongoing study continues to indicate that significant ecological changes including effects on flora are associated with *L. claviger* in the 26-year old Russell R. Kirt reconstructed prairie. These changes persist in contrast to decreased heterogeneity findings at the Fermi Lab prairie (Lane and BassiriRad 2005). Reasons may include differences in the composition of underlying substrates, plot sizes, interactive affects of existing fauna, and the resource pools for and dispersal rates of colonizers. Other studies involving natural and grazed areas of varying sizes and floral communities indicate persistent soil heterogeneity created by ground-dwelling ants even for some time after an anthill has been abandoned (Beattie and Culver 1977, Dauber et al. 2001, Jurgensen et al. 2008, Kristiansen and W. Amelung 2001, Lesica and Kannowski 1998). Continued study is warranted to test for differences in ecological succession when areas are occupied by *L. claviger* and other mound-building ants versus when they lack mound-building colonies. Such extended studies are needed to elucidate the roles of ants in regulating the underlying biotic and physical factors affecting succession within reconstructed sites and optimizing conservation goals.

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